



Southeast Alaska Network Freshwater Water Quality Monitoring Program

2011 Annual Report

Natural Resource Technical Report NPS/SEAN/NRTR—2012/561



ON THE COVER

Bridge over the Indian River in Sitka National Historical Park

Photograph by: Christopher J. Sergeant, Southeast Alaska Network, National Park Service

Southeast Alaska Network

Freshwater Water Quality Monitoring Program

2011 Annual Report

Natural Resource Technical Report NPS/SEAN/NRTR—2012/561

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Executive Summary

Freshwater water quality is an indicator of ecosystem health and one of twelve priority Vital Signs monitored in the National Park Service's Southeast Alaska Network (SEAN). In 2011, hourly water temperature, conductivity, dissolved oxygen, and pH data were collected in the Salmon River (GLBA) from May 31 through September 30, and in the Indian River (SITK) from June 28 through September 27. The same parameters plus turbidity were collected in the Taiya River (KLGO) from April 25 through July 25 and September 14 through November 14. In future years, data collection is planned to regularly occur from May 1 through October 31 as ice conditions allow.

Annual reports are concise but thorough summaries of the previous season's data that establish a regular product for park staff, managers, superintendents, and other interested parties. This is the second annual water quality report from the SEAN, representing the continuation of a sustained effort to collect long-term, high resolution water quality data in Southeast Alaska National Parks. This document analyzes the second year of data from GLBA and SITK, and the first year for the Taiya River at KLGO. All annual reports and data products are available at the SEAN freshwater water quality website:

http://science.nature.nps.gov/im/units/sean/FQ_Main.aspx

The Salmon and Indian Rivers demonstrated similar seasonal temperature trends to 2010. 2011 daily mean water temperature in the Salmon River ranged from 5.8 to 10.7°C, peaking on July 23, while daily mean water temperature in the Indian River ranged from 6.6 to 10.0°C, peaking on August 20. The Salmon and Indian Rivers have non-overlapping seasonal medians for conductivity, dissolved oxygen, and pH, but patterns within each river for these parameters were similar between 2010 and 2011 monitoring years.

Due to the strong influence of glacial meltwater, the Taiya River demonstrated dynamic fluctuations in water temperature, especially May through July, and had a lower median temperature than the mostly ground- and surface-water influenced Salmon and Indian Rivers. In 2011, daily mean water temperature in the Taiya River ranged from 0.3 to 6.9°C, peaking on July 13, with a median of 5.1°C. The ranges of seasonal values for conductivity, dissolved oxygen, and pH were quite small across the season. Turbidity was variable throughout 2011, ranging from 1.0 to 229.6 NTU, and was correlated with high flow events caused by heavy rain and glacial melt.

During a warm/dry period on the Taiya River, median conductivity and pH values dropped slightly over time, while median water temperature and DO levels varied but did not demonstrate directional trends. During a cool/wet period water temperature dropped slightly and demonstrated less daily range than during the warm/dry period. Turbidity spikes during the cool/wet period were much greater than during the warm/dry period. Conductivity slowly rose, while DO and pH demonstrated little change.

No observed values or trends appeared to signal point source pollution or a change to the fundamental water quality of the Salmon, Taiya, or Indian Rivers. Throughout the monitoring period, all three rivers exhibited water quality conditions within expected ranges.

Acknowledgments

J. Guth, M. Lehmann, C. Murdoch, C. Smith, C. Soiseth, and J. Wilbarger conducted field work and transmitted data for processing. J. Wilbarger also created study area maps and provided a valuable review of the draft report. The SEAN Vital Signs program is supported by funding from the NPS National Inventory and Monitoring Program and the NPS Water Resources Division.

List of Acronyms

DO:	Dissolved oxygen
mS	Milli-Siemens
NPS:	National Park Service
NTU	Nephelometric Turbidity Units
GLBA:	Glacier Bay National Park and Preserve
KLGO:	Klondike Gold Rush National Historical Park
SEAN:	Southeast Alaska Network
SITK:	Sitka National Historical Park
SOP:	Standard Operating Procedure
USGS:	United States Geological Survey

Introduction

Water quality is an indicator of aquatic and terrestrial ecosystem health in Southeast Alaska, a rainforest landscape dominated by a wet and mild maritime climate. The Southeast Alaska Network (SEAN; Figure 1) of the National Park Service (NPS) has prioritized Freshwater Water Quality as one of 12 Vital Signs for long-term ecological monitoring based on its vulnerability to alteration by human stressors and sensitivity for detecting fundamental environmental changes (Moynahan et al. 2008). Trends in water quality can signify chronic or developing watershed issues within national parks.

The SEAN water quality monitoring program has the following objectives:

- Track the status and trends of each core water quality parameter (conductivity, dissolved oxygen, pH, and water temperature; plus turbidity in the Taiya River)
- Describe the timing and magnitude of seasonal and annual variation for each core water quality parameter
- Evaluate whether state and/or federal water quality standards are met or exceeded

The SEAN water quality monitoring protocol (Nagorski et al. 2012) includes an extended description of each water quality parameter (Sections 1.3-1.7). Briefly, conductivity measures the ability of water to conduct an electrical current, with higher values generally representing groundwater influence and lower values representing rain and snow runoff. Dissolved oxygen is a measure of the amount of microscopic oxygen bubbles in water and is essential for aquatic organism respiration. The unit-less pH measures the acidity or alkalinity of a solution and affects aquatic organism respiration, salt exchange, and many biogeochemical processes. Turbidity is a measure of water clarity.

Section 7.0 of the monitoring protocol discusses future priorities for expanding the monitoring program. We expect future monitoring to include an expanded stream temperature component and potentially additional water quality sondes to currently unmonitored rivers within the SEAN.

This report summarizes results from the 2011 sampling season and compares historical data in the same rivers or similar systems, where data was available. Additional analyses are provided for the first year of data for the Taiya River to provide a broader context for its water quality trends, similar to those presented for the Salmon and Indian Rivers in the 2010 report. It should be noted that the 2010 and 2011 reports were written in early 2012 after data management processes were finalized. Future annual reports will be drafted within approximately three months of the end of the previous field season. Every five years, starting after the completion of the 2014 field season, a five-year synthesis report will present more in-depth trend analyses and broadened discussion. Guidance for annual report formatting and analytical techniques is described in Standard Operating Procedure (SOP) 10 of the water quality monitoring protocol (Nagorski et al. 2012).

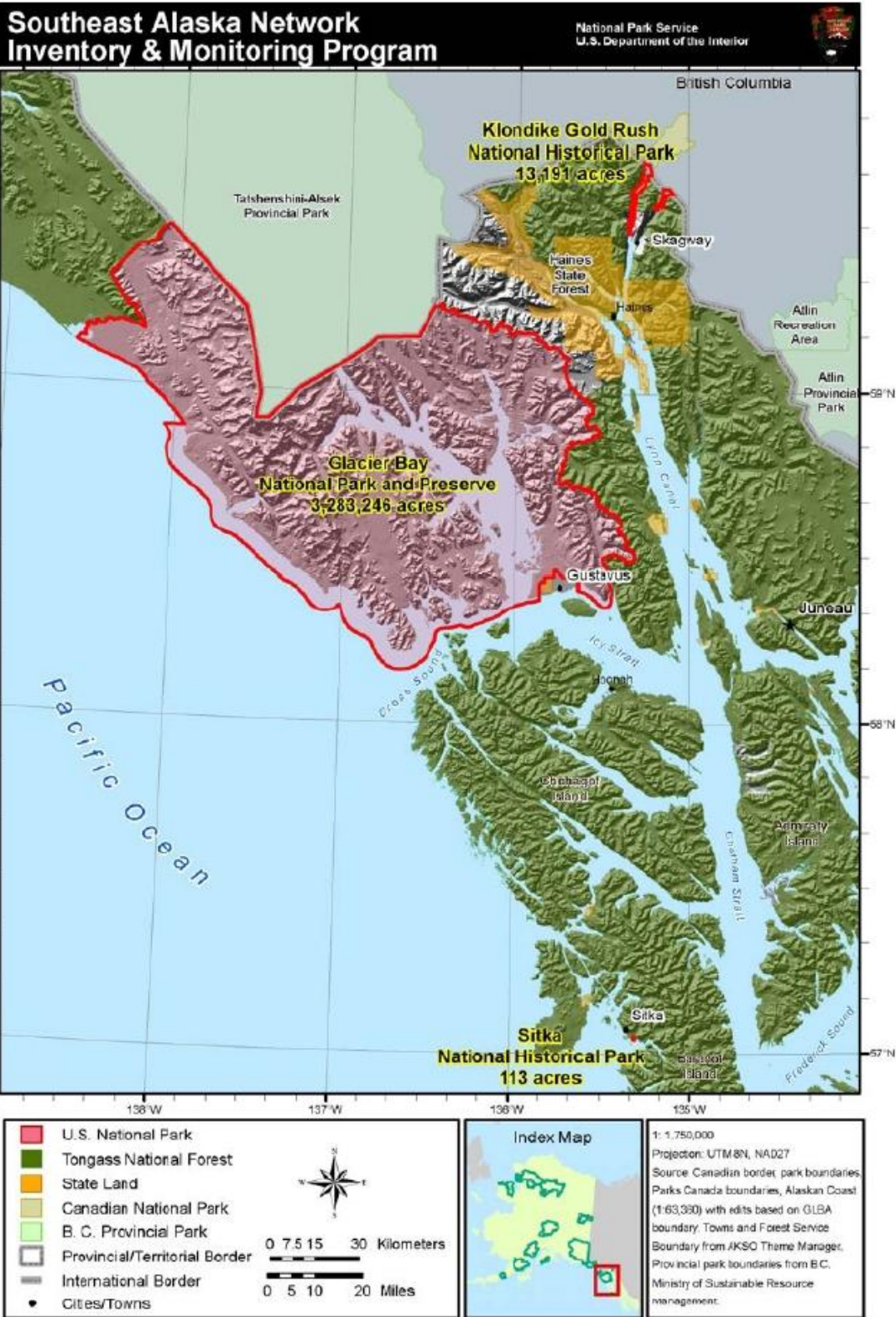


Figure 1. Overview of SEAN park locations and surrounding lands.

Study Areas

The initial sampling goal of the monitoring program was to track water quality status and trends in at least one river in each of the three SEAN parks. In 2010, sondes were installed in the Salmon (GLBA) and Indian (SITK) Rivers. The Taiya River (KLGO) was added in 2011. Sampling sites were chosen based on park prioritization and dependable site access. Until the SEAN freshwater water quality monitoring program began, no consistent or long-term data collection has taken place in these three rivers (Eckert *et al.* 2006a; Eckert *et al.* 2006b; Hood *et al.* 2006).

Salmon River (GLBA)

GLBA, the largest unit in SEAN, has more than 310 streams (Soiseth and Milner 1995, NPS 2005) flowing for over 3,380 km through a diverse landscape, making this park a priority area for future water quality monitoring program expansion. The Salmon River is 32.7 km long within an 11,552 ha watershed that collects most of its water from Excursion Ridge. The lowermost portion of the river (river km 0.0 to 9.0) is outside of NPS boundaries and within the town of Gustavus. The Salmon River has gravel riverbed habitat and supports populations of gamefish species such as pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*O. keta*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), cutthroat trout (*O. clarkii*), and Dolly Varden (*Salvelinus malma*; Eckert *et al.* 2006a). Staghorn (*Leptocottus armatus*) and coastrange sculpin (*Cottus aleuticus*) have been documented in the river but not formally reported (C. Soiseth personal communication). Although there is no direct evidence from past data, due to septic system design and proximity, sewage input from Gustavus residents may affect Salmon River water quality downstream of the park boundary and sampling site. The water quality monitoring site is located on the river left bank at approximately river km 9.0 (Figure 2) several meters upstream of the NPS boundary.

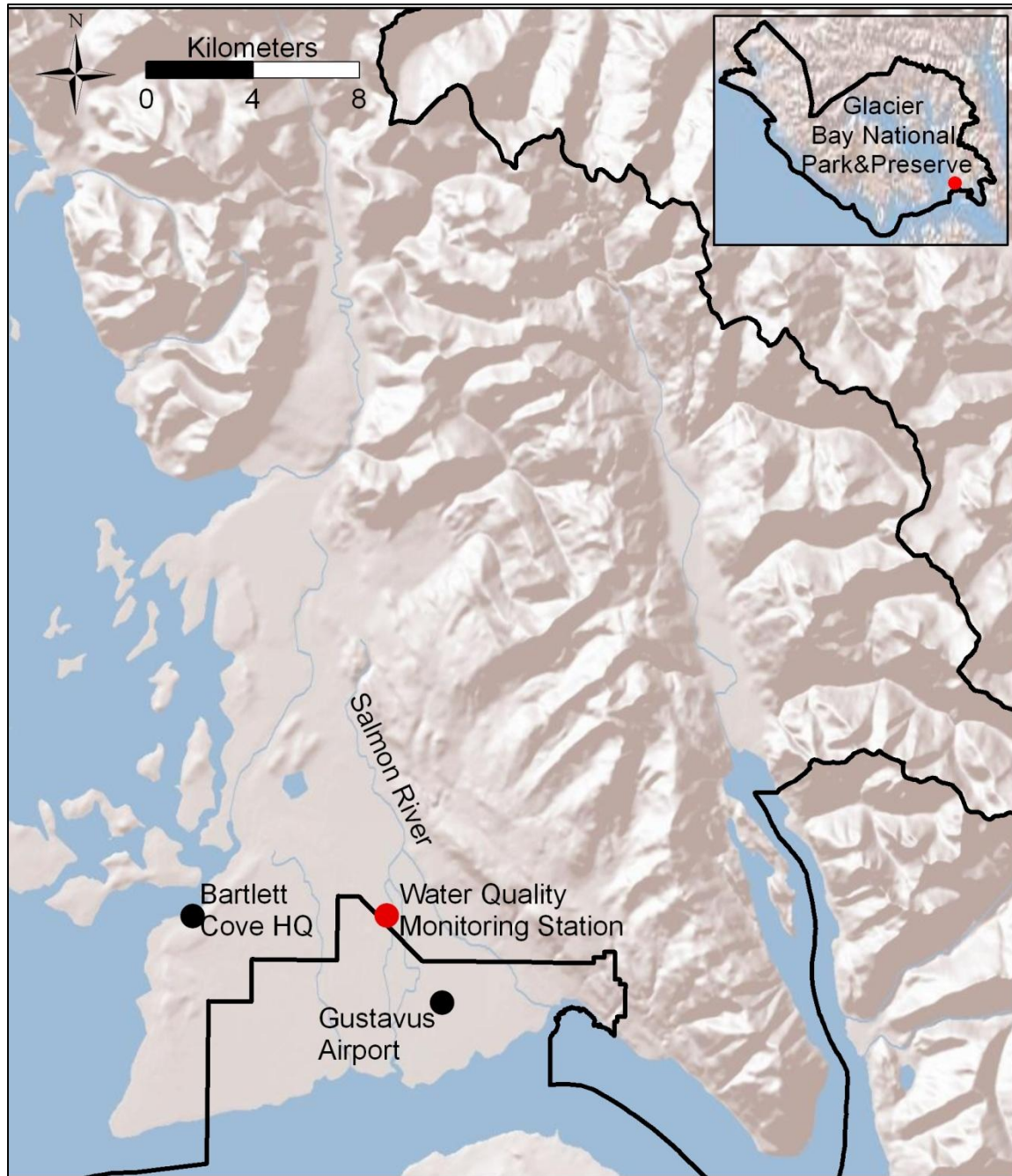


Figure 2. Monitoring station on the Salmon River in GLBA (red circle near S edge of map). The black line denotes park boundary.

Taiya River (KLGO)

The Taiya River, located west of Skagway and one of two major drainages in KLGO, is approximately 25.7 km long and drains a watershed of approximately 46,361 ha (Hood *et al.* 2006). The water quality monitoring site is located on the river left bank slightly downstream of the Taiya River bridge (Figure 3) and adjacent to the USGS streamflow gaging site. From 1970 to 2010, the annual mean discharge from the Taiya has ranged from 24.9 (879 cfs; 1973) to 40.3 $\text{m}^3 \text{s}^{-1}$ (1423; 2004). Peak flows typically occur in August and September (USGS website for

Taiya River gage 15056210:

http://waterdata.usgs.gov/nwis/nwisman/?site_no=15056210&agency_cd=USGS).

Skagway is notably drier than other Southeast Alaska communities, averaging 69 cm of precipitation per year, in comparison to 139 cm in Gustavus and 217 cm in Sitka and (Western Regional Climate Center Data: <http://www.wrcc.dri.edu/summary/Climsmak.html>). The glacial influence on the Taiya watershed is unique among streams currently monitored in the SEAN. As of the mid-1990s, approximately 33% of the watershed was covered by glaciers (Hood *et al.* 2006). Glacial outburst events have led to large flooding events and created a highly dynamic physical environment (Hood *et al.* 2006). The Taiya watershed supports chum, pink, and coho salmon populations, as well as Dolly Varden. Eulachon (*Thaleichthys pacificus*) have been reported to run up the Taiya River in the spring (Hood *et al.* 2006).

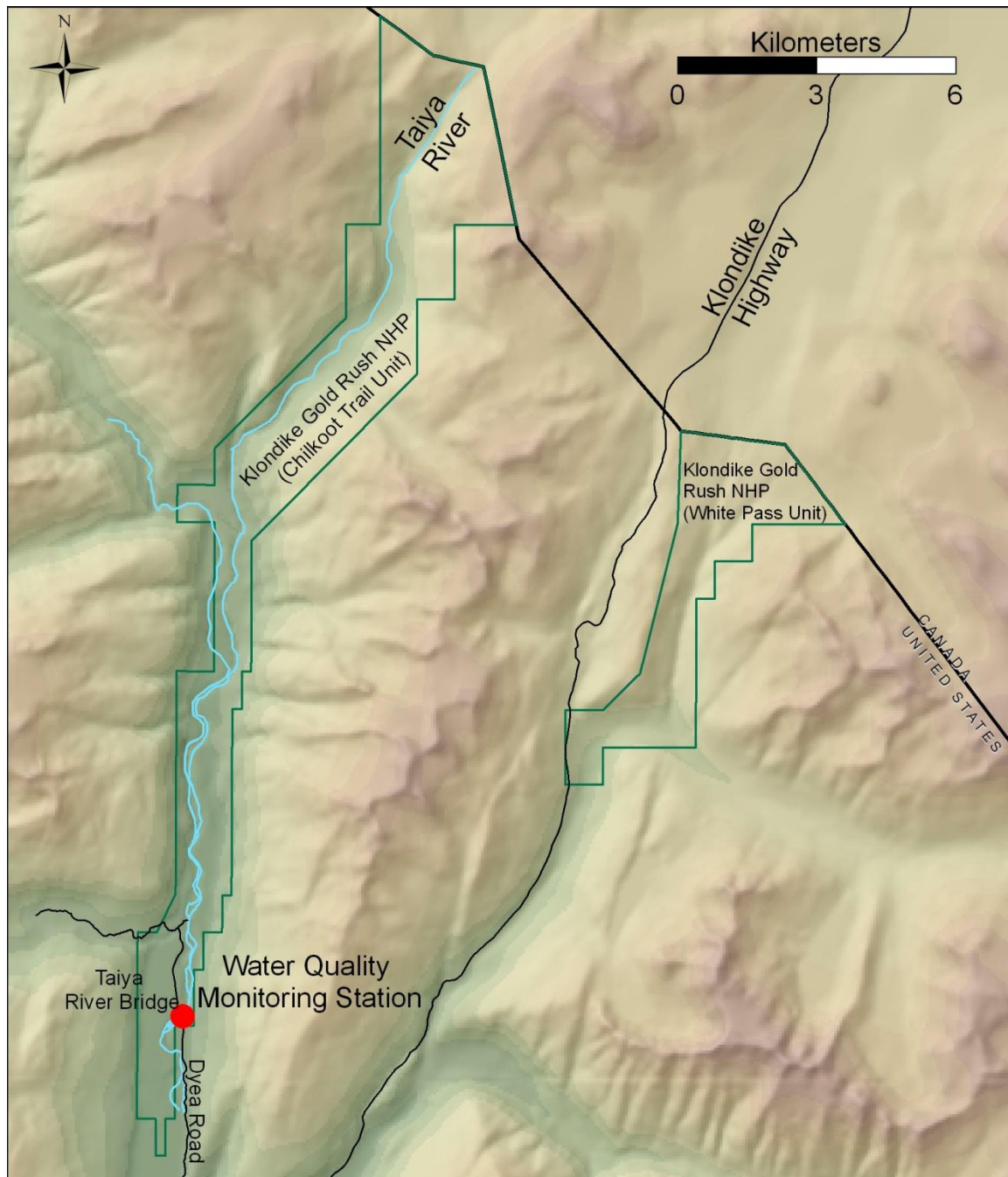


Figure 3. Monitoring station on the Taiya River in KLGO (red circle near SW corner of map). The green lines denote park boundaries.

Indian River (SITK)

The lowest 1 km of the Indian River is the only significant riverine habitat within the SITK boundary and can be characterized as a low gradient alluvial channel with gravel-cobble substrate (Eckert et al. 2006b) that supports anadromous fish species, including coho, pink, chum, and Chinook salmon (*O. tshawytscha*), steelhead, Dolly Varden, and non-anadromous species such as resident rainbow trout (*O. mykiss*), three-spine stickleback (*Gasterosteus aculeatus*), and coastrange sculpin (Eckert et al. 2006b). The Indian River is approximately 19.8

km long within a steep and well-drained 3,185 ha watershed. The water quality monitoring site is located on the river right bank approximately 60 m upstream of park boundaries at river km 0.8 (Figure 4).

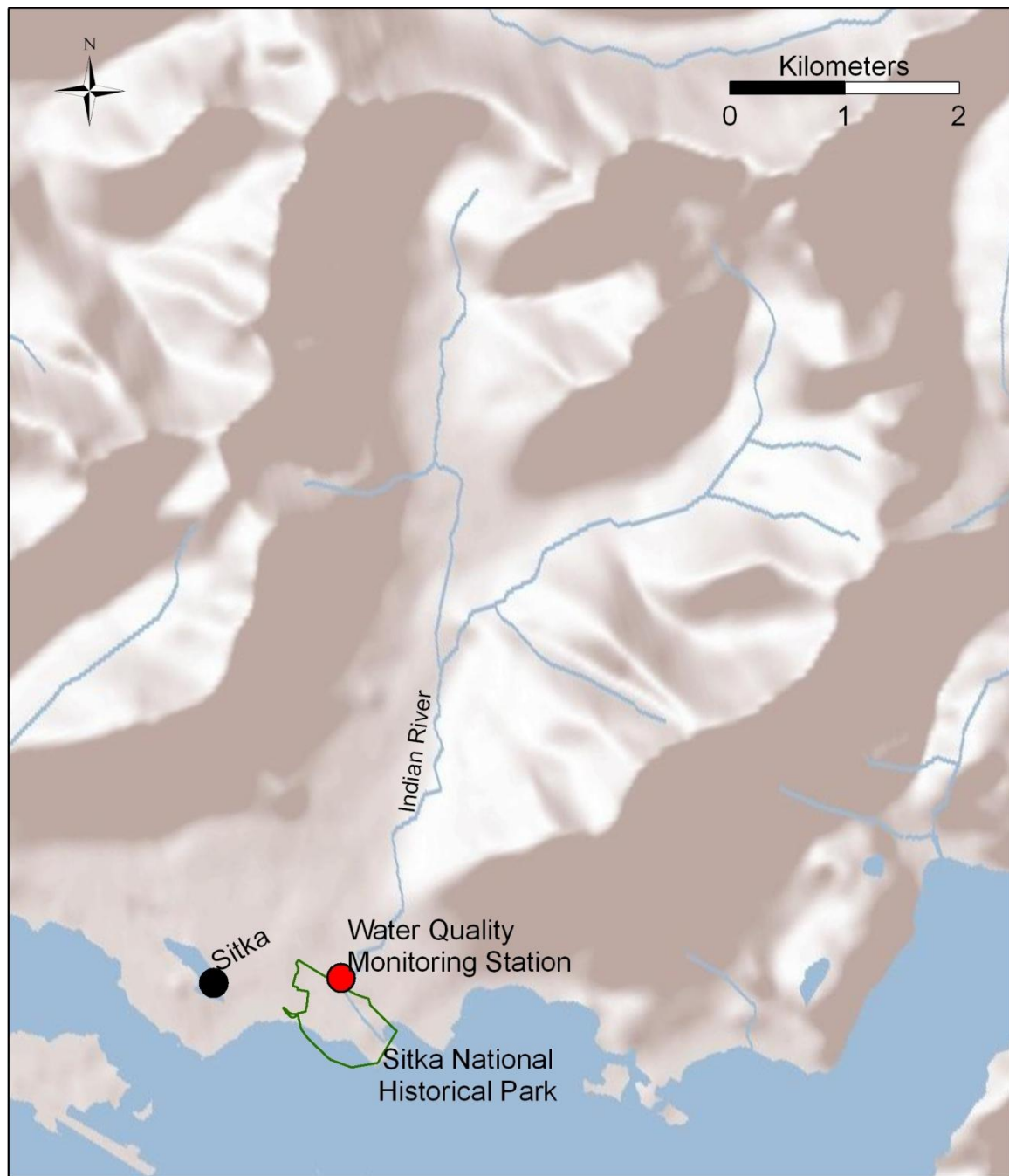


Figure 4. Monitoring station on the Indian River in SITK slightly upstream of park boundary (red circle near SW corner of map). The green line denotes park boundaries.

Methods

Station instrumentation

The Salmon, Taiya, and Indian Rivers were sampled hourly for conductivity (specific conductance; mS/cm), dissolved oxygen (mg/L), pH, and water temperature (°C). Turbidity (NTU) was measured in the Taiya River only. Multi-parameter water quality sondes (Table 1) collected and logged data at single fixed sites (Figures 2-4) in the Salmon River, from May 31 through September 30, the Taiya River from April 25 through July 25 and September 14 through November 14, and the Indian River from June 28 through September 27 (Table 2). In future years, sampling is planned to regularly occur from May 1 through October 31, possibly into November if ice conditions and staff resources allow.

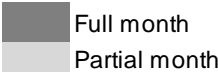
Table 1. YSI, Inc. instruments used for 2011 water quality sampling.

Equipment description	Model number
Multi-parameter water quality logger	6920V2-2
Multi-parameter display system	650
Conductivity/temperature probe	6560
pH probe	6561
Optical oxygen sensor	6150
Optical turbidity sensor	6136

In all three rivers, a sonde was mounted inside a perforated 4-inch ABS pipe. In the Salmon River a pipe was attached to an angle-iron rod set into the streambed, while in the Taiya and Indian Rivers a pipe was bolted to a large boulder in the stream channel. A bolt mounted through the ABS pipe set the sonde height in the water column. When sondes were installed, Park Leads generally visited the sondes once a month to check calibration for each sensor and clean components, as needed. These calibration checks were used to assess data quality and ensure that the water quality instruments were functioning properly.

Table 2. Summary of 2011 freshwater water quality sampling effort.

River	Month								Core parameters collected?
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	
Salmon									Y
Taiya									Y
Indian									Y



Data processing

The protocol narrative, SOP 1, and SOP 2 describe the data collection, calibration checks, and data processing in detail (Nagorski et al 2012). Park staff conducted calibration checks on the Salmon River within one week of the first day of each month from June to September until instrument removal on September 30. On the Taiya River, calibration checks were also conducted within one week of the first day of May, June, and October until instrument removal in November, but a broken download cable connector prevented the July check. On the Indian River, where the sonde was not installed until June 28 due to instrument leakage, one calibration check took place on August 5 and no others until instrument removal on September 27. A

September calibration check was not possible due to gravel in the ABS pipe impeding removal of the sonde for download. It was decided that it was better to leave the sonde in place collecting data for another month than to possibly break the sonde trying to pry it loose from the ABS mounting pipe.

SEAN has established data “ratings” and “grades” to describe overall data quality. “Ratings” denote unusable data for reasons such as the sonde being out of water during a calibration check or a spurious value due to instrument error. Before analysis, data with a ‘2’ or ‘3’ quality rating were removed from the analyzed data set. Data with ‘0’ (no question of accuracy) or ‘1’ (determined useable by Project Leader despite potential mistakes in following protocols) data quality ratings were not deleted from the data summaries. SOP 13 of the water quality protocol (Nagorski et al. 2012) describes each data rating in detail. Comments contained in the water quality database are available on the SEAN website (http://science.nature.nps.gov/im/units/sean/FQ_Main.aspx) and contain justifications for each rating. Data “grades” refer to the point-in-time accuracy of each water quality sensor during regular calibration checks and range from ‘Poor’ to ‘Excellent’. The grades determined by these point checks were back-dated to the previous calibration check and applied to all data during that time period. Currently, SEAN does not correct (adjust) data values based on calibration checks (as described in Wagner et al. 2006), but will develop a proposal for future consideration of data correction procedures around early 2013.

The final data sets were analyzed and summarized according to the guidelines in SOP 10 (Nagorski et al. 2012).

Comparison of cool/wet versus warm/dry periods

In the 2010 annual report, hourly readings for short time periods from the Salmon and Indian Rivers compared fine-scale water quality trends during warm/dry versus cool/wet periods. This analysis was repeated in 2011 for the Taiya River. To determine warm/cool air temperatures and dry/wet periods of precipitation, weather data were taken from the Skagway airport. These summaries are intended to characterize each system’s general physicochemical dynamics in response to opposing patterns of air temperature and precipitation. Monotonic directional trends for each water quality parameter were determined using the Mann-Kendall test (R Package ‘wq’; Jassby and Cloern 2011). The non-parametric Mann-Kendall test evaluates whether a dependent Y-axis variable (e.g., temperature) changes over time in a positive or negative direction regardless of the function’s shape. The test is robust for water quality data that are typically not normally distributed. Analyses will not be replicated in future annual reports unless the general patterns shift.

Results

Data collection

Some problems were encountered with data collection in all three rivers during portions of the 2011 sampling season. In the Salmon River, one month of data was lost from May 1 through May 30 due to an improperly programmed sonde. In the Taiya River, problems with sonde electrical connections required a mid-season factory repair that created a gap in data collection from July 26 through September 13. Manufacturing flaws caused a leaking oxygen sensor in the Indian River sonde and resulted in the complete suite of water quality sensors malfunctioning and delaying the start of data collection until June 28.

Data grades could not be calculated for Salmon River temperature from September 8 to September 30 due to a faulty calibration thermometer. Data grades could not be calculated for any parameters in the Taiya River from June 7 to July 25 because of a faulty wiring connection in the sonde and grades could not be calculated for conductivity and turbidity from September 14 to September 30 because proper calibration procedures were not followed. From August 5 to September 27, Indian River data grading was not possible because the sonde was inaccessible and wedged in the mounting tube by substrate that entered during a high flow event. Data grades could not be assigned because the calibration procedures were not performed during this period. Despite these data grading gaps, the reported water quality parameter values in the figures below appear very reasonable based on observed 2010 data values.

Table 3. Summary of 2011 freshwater water quality data grades. E = Excellent, G = Good, F = Fair, P = Poor. Definitions for each grade are found in SOP 2 (Nagorski et al. 2012) and are based on USGS recommendations (Wagner et al. 2006). These recommendations include data correction for periods when data grades are less than 'Excellent', but at this time, SEAN has not finalized protocols for applying corrections.

		Date ranges				
River	Parameter	5/31 - 7/1	7/1 - 9/8	9/8 - 9/30		
Salmon	Conductivity (mS/cm)	E	E	P		
	Dissolved Oxygen (mg/L)	G	E	E		
	pH	E	E	E		
	Temperature (°C)	P	F			
		Date ranges				
		4/25 - 5/2	5/2 - 6/7	6/7 - 7/25	9/14 - 9/30	9/30 - 11/14
Taiya	Conductivity (µS/cm)	G	G			G
	Dissolved Oxygen (mg/L)	E	E		E	E
	pH	E	E		E	E
	Turbidity (NTU)	G	P			P
	Temperature (°C)	E	E		E	G
		Date ranges				
		6/29 - 8/5	8/5 - 9/27			
Indian	Conductivity (µS/cm)	E				
	Dissolved Oxygen (mg/L)	E				
	pH	E				
	Temperature (°C)	E				

Comprehensive time series data

Hourly time series data for all water quality parameters in all three rivers are included in Appendix A. Daily average streamflow time series data from the Taiya River are compared to daily average water quality data in Appendix B. Streamflow data was collected in close proximity to water quality data. At the time of this report, Indian River streamflow data was not available.

Salmon River

Temperature

Temperature trends in the Salmon River were generally similar across the entire sampling season between 2010 and 2011 (Figure 5) but showed some divergence during isolated time periods. In 2011, the river stayed cooler for a longer period during late spring and a portion of late summer periods than in 2010. Through July, the river was warmer in 2011 than 2010 (monthly averages 9.5°C versus 8.8°C, respectively; Table 4). In 2011, daily mean water temperature in the Salmon River ranged from 5.8 to 10.7°C, peaking on July 23 (22 days earlier than 2010).

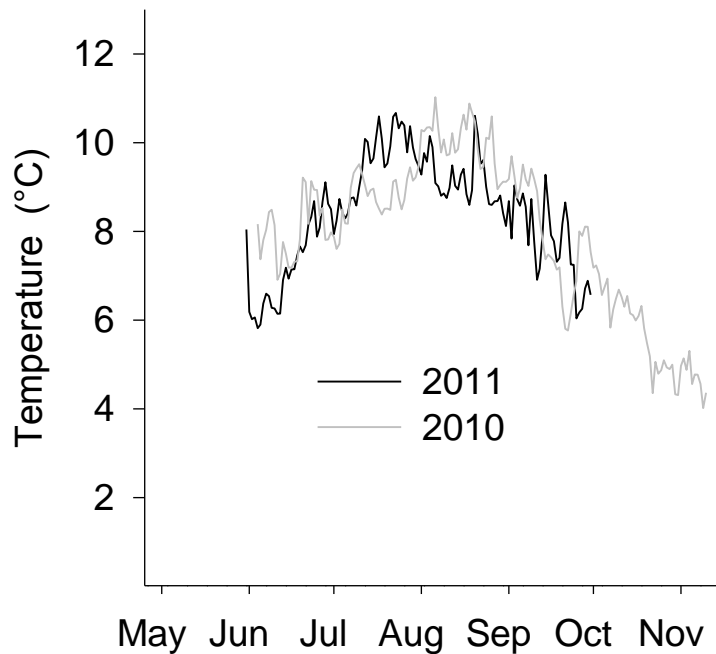


Figure 5. Daily mean water temperature for the Salmon River in 2010 and 2011.

Table 4. Monthly mean, minimum daily mean, and maximum daily mean water temperature for the Salmon, Taiya, and Indian Rivers in 2011. See the methods section for sonde installation dates for each river.

	Salmon			Taiya			Indian		
Month	Mean daily average (SD)	Min	Max	Mean daily average (SD)	Min	Max	Mean daily average (SD)	Min	Max
May				4.8 (0.4)	4.0	5.6			
June	7.2 (1.0)	5.8	9.1	5.6 (0.4)	4.4	6.5			
July	9.5 (0.8)	7.9	10.7	6.3 (0.5)	5.4	6.9	8.0 (0.5)	7.1	8.9
August	9.1 (0.6)	8.1	10.6				8.0 (0.6)	7.4	10.0
September	7.8 (0.9)	6.0	9.3				7.7 (0.6)	6.6	8.7
October				4.5 (0.4)	3.8	5.2			

Conductivity, DO, and pH

The 2011 ranges for conductivity, DO, and pH values in the Salmon River (Figure 6) were generally similar to 2010, although direct comparisons of the distributions are difficult due to differing sampling windows between years. In 2011, daily average conductivity ranged from 0.07 to 0.32 mS/cm with a median of 0.19 mS/cm. DO ranged from 9.1 to 12.4 mg/L with a median of 10.2 mg/L. During June and July, DO demonstrated less daily variation than the larger ranges observed August onward. DO steadily dropped over June and July, reaching its minimum value of 8.5 mg/L on July 24 (Appendix A; Figure 12). Values for pH ranged from 7.3 to 7.9 with a median of 7.8. Values were relatively stable through July but began demonstrating great variation from August onward.

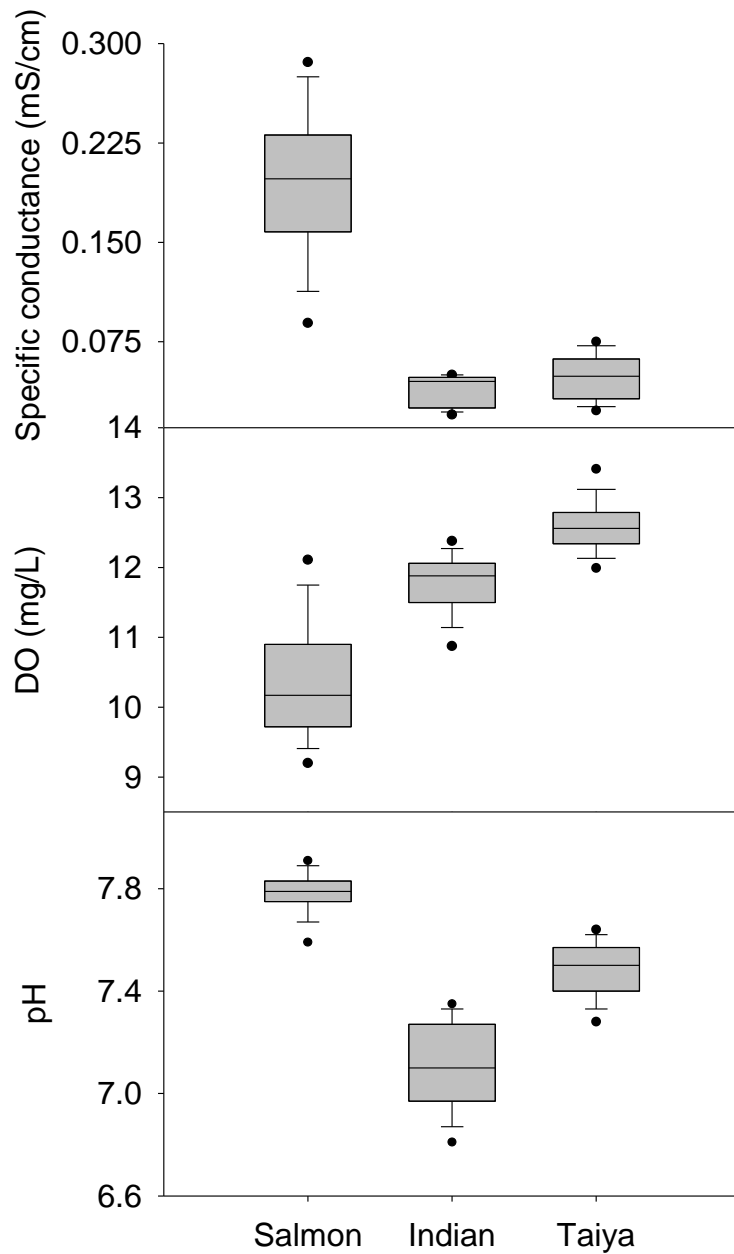


Figure 6. Box plots summarizing collected values for pH, dissolved oxygen (DO), and specific conductance for the Salmon, Taiya, and Indian Rivers in 2011. The central horizontal line within each box indicates median values, horizontal lines bounding the upper and lower portion of the boxes represent 25th and 75th percentiles, lower and upper whiskers represent 10th and 90th percentiles, and single points represent 5th and 95th percentiles.

Taiya River

Temperature

2011 water temperature values in the Taiya River demonstrated two distinct patterns, a highly variable, but warming, spring and summer period, and a less variable and quickly cooling fall period (Figure 7; Appendix A; Figure 13). In 2011, daily mean water temperature in the Taiya River ranged from 0.3 to 6.9°C, peaking on July 13, with a median of 5.1°C.

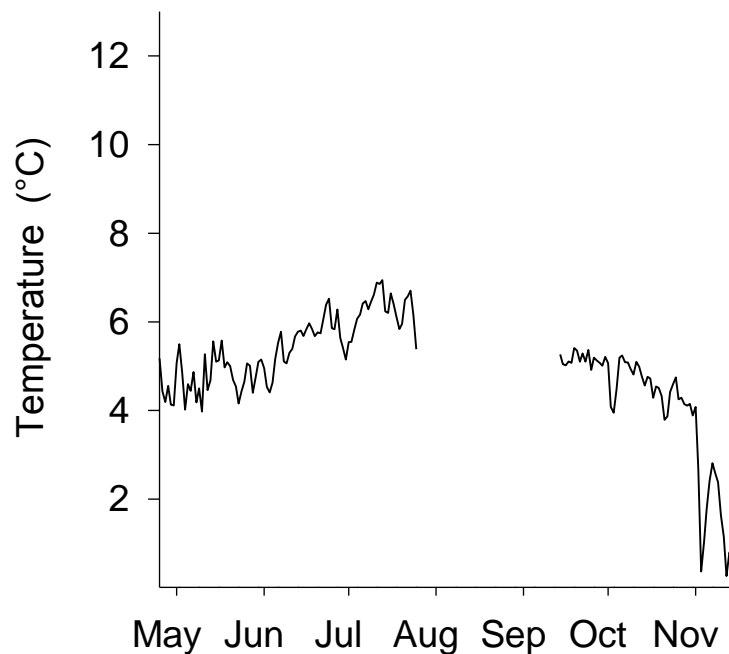


Figure 7. Daily mean water temperature for the Taiya River in 2011 (no data collected in 2010).

Turbidity

In 2011, Taiya River turbidity ranged from 1 to 229.6 NTU during the sampling season, with larger peak events occurring in spring and fall (Figure 8). Turbidity remained low before mid-May and after October, when cooler temperatures moderate or prevent glacial melt. Both warm (Figure 9) and wet (Figure 10) periods induced higher turbidity events in the Taiya River. Turbidity events were reliably timed with high flow events (Appendix B; Figure 15).

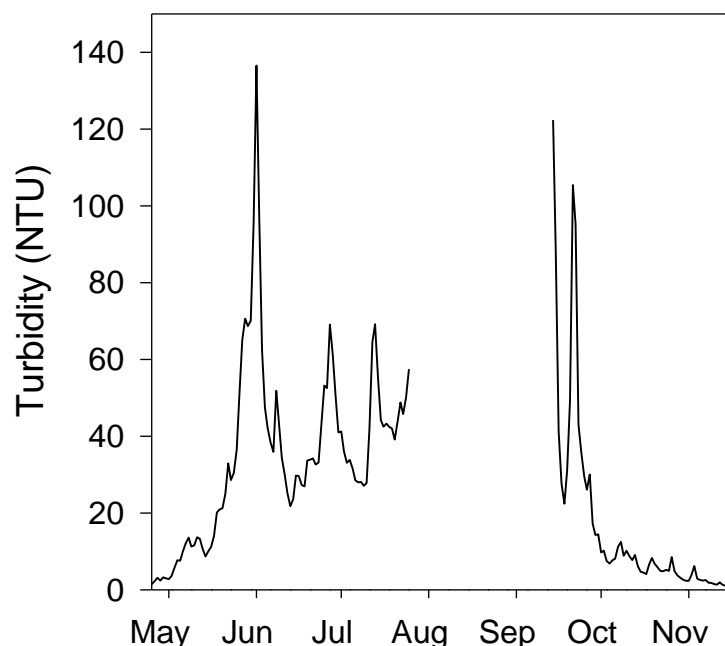


Figure 8. Daily mean turbidity for the Taiya River in 2011.

Conductivity, DO, and pH

In the Taiya River in 2011, daily average conductivity ranged from 0.02 to 0.08 mS/cm with a median of 0.05 mS/cm. From May through late July, conductivity steadily dropped, while after mid-September, values began steadily rising (Appendix A; Figure 13). DO ranged from 12.1 to 14.1 mg/L with a median of 12.5 mg/L. From May through late July, DO demonstrated greater daily variation than that observed after mid-September (Appendix A; Figure 13). Values for pH ranged from 7.2 to 7.9 with a median of 7.5.

Warm/dry versus cool/wet water quality patterns

Plots for warm/dry periods versus cool/wet periods provide a general summary of high-resolution, short-term water quality trends in the Taiya River (Figures 9 and 10). Each figure displays the same axes scales for consistent trend comparisons across times and locations. Monotonic directional trends for water temperature, conductivity, and pH during each weather pattern were quite small, but statistically significant using the Mann-Kendall non-parametric test for trend. Dissolved oxygen did not demonstrate a significant directional trend during either weather pattern. Directional trends for conductivity and pH switched between warm (both parameters falling) and cool (both parameters rising) periods. These trends should be interpreted cautiously, as autocorrelation tends to lower p-values and since these short-term data sets were chosen systematically, but strictly for illustrative purposes.

During a warm/dry period on the Taiya River from July 9 through July 18 (Figure 9), DO, water temperature, and turbidity demonstrated the greatest diel variation. Conductivity and pH values exhibited much slighter diel variation. Median conductivity and pH values dropped slightly during this period (Mann-Kendall test; $p < 0.001$), while median water temperature and DO levels did not demonstrate significant directional trends ($p = 0.94$ and 0.11 , respectively).

During a cool/wet period on the Taiya River from September 19 through September 30 (Figure 10), water temperature continued to demonstrate diel variation, but much less daily range compared to the warm/dry period. Turbidity spikes during the cool/wet period were much greater than during the warm/dry period. Conductivity was variable during the cool/wet period and slowly rising ($p < 0.001$). DO and pH demonstrated little change during the cool/wet period. Median water temperature dropped slightly during this period ($p = 0.004$), while median pH rose slightly ($p < 0.001$). In comparison to the mostly ground- and surface-water dominated Salmon and Indian Rivers, the glacial meltwater dynamics of the Taiya River complicate interpretation of the difference in water quality trends during differing atmospheric conditions.

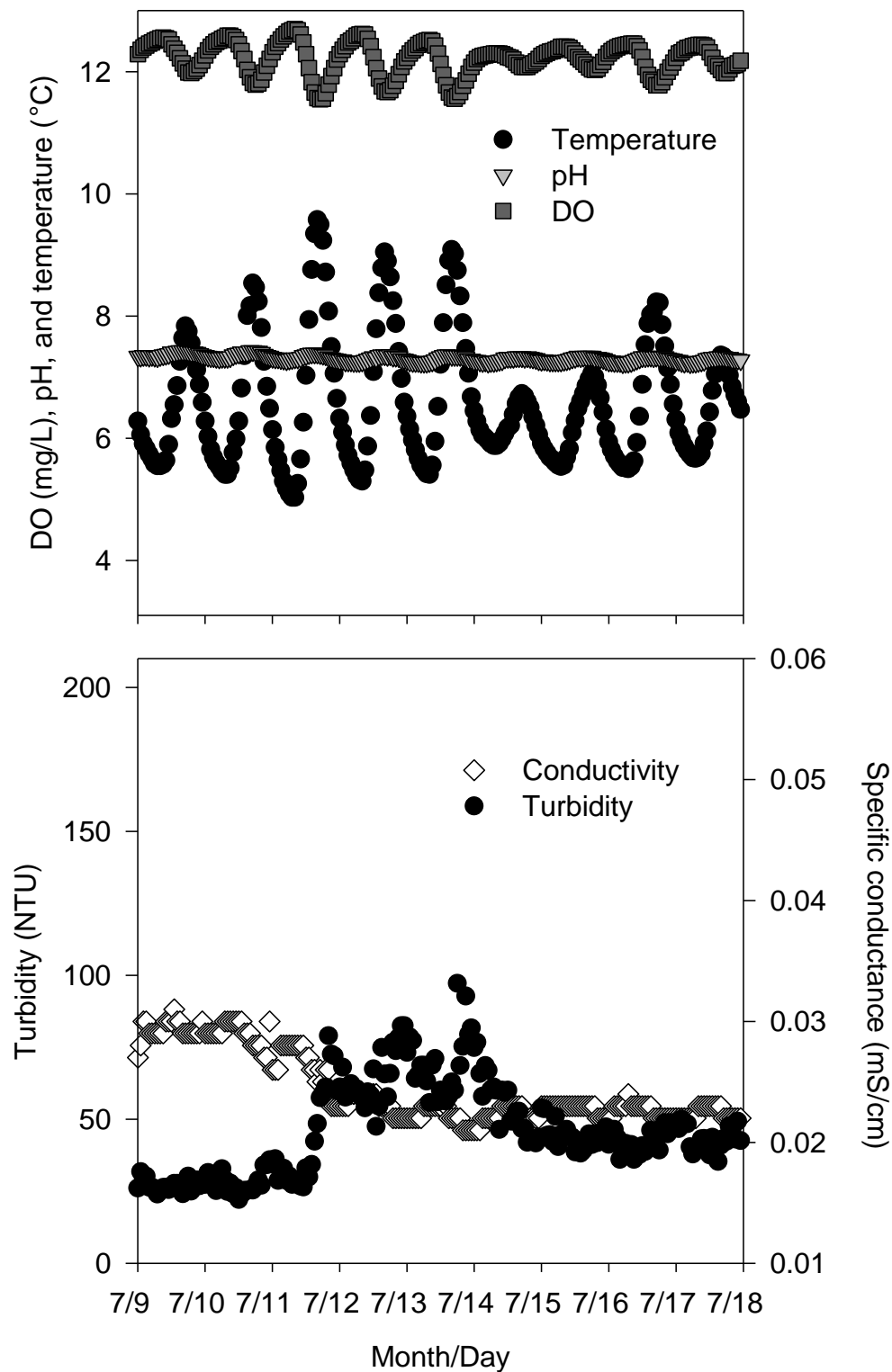


Figure 9. Hourly water quality readings of DO, pH, water temperature, conductivity, and turbidity for the Taiya River during a representative 2011 warm/dry period. During this date range, no rainfall was recorded at the Skagway airport and average daily air temperatures ranged from 13.9 to 16.7°C. Note the second axis in the lower panel for specific conductance values.

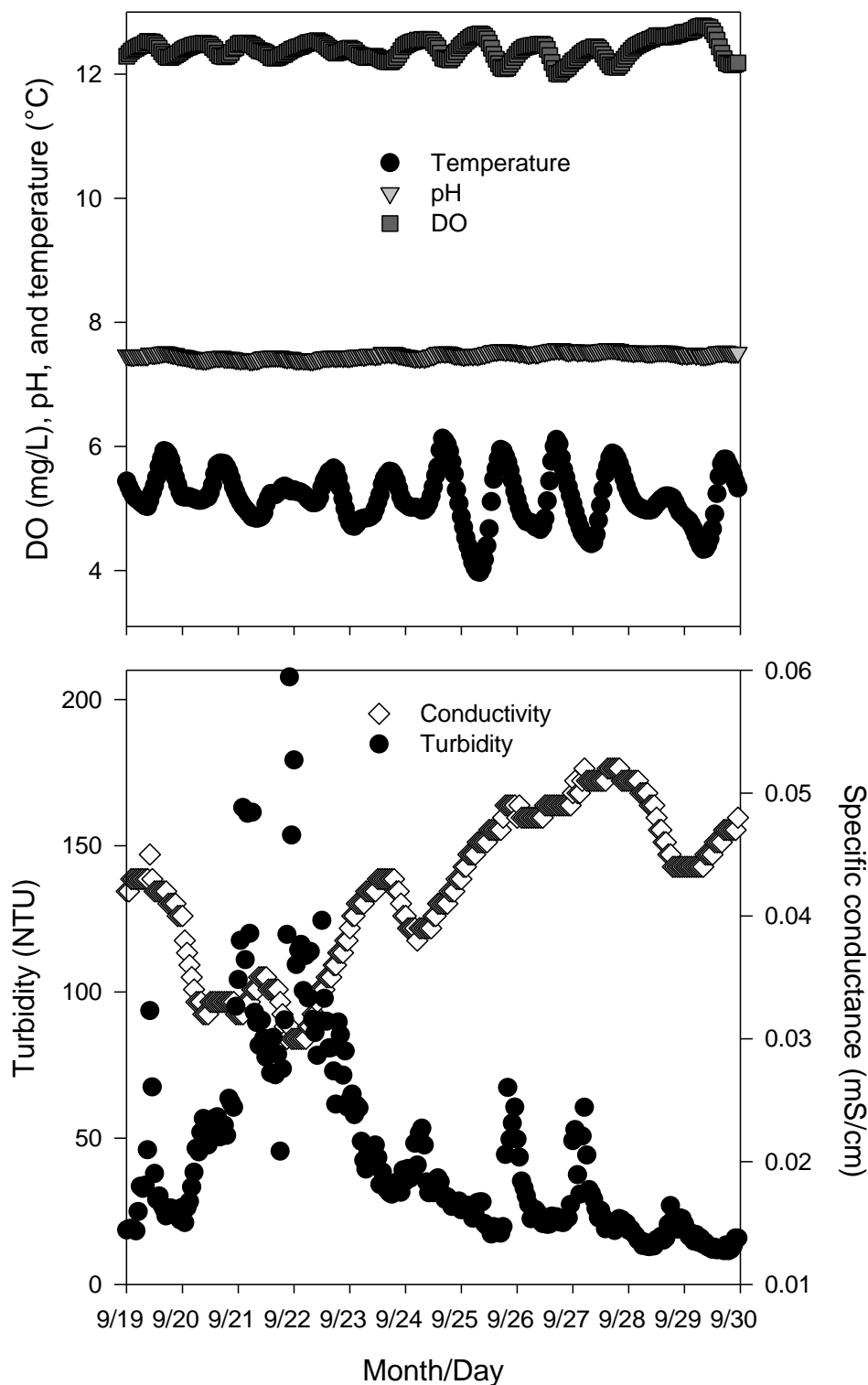


Figure 10. Hourly water quality readings of DO, pH, water temperature, conductivity, and turbidity for the Taiya River during a representative 2011 cool/wet period. During this date range, average daily rainfall at the Skagway airport ranged from 0.00 to 2.87 cm, and average daily air temperatures ranged from 6.7 to 11.1°C. Note the second axis in the lower panel for specific conductance values.

Indian River Temperature

The magnitude of water temperature trends in the Indian River was generally similar across the 2010 and 2011 sampling seasons (Figure 11), but showed some divergence during isolated time periods. In 2011, the river stayed warmer during late July and late September than in 2010. Through most of August, the river was cooler in 2011 than 2010 (monthly averages 8.0°C versus 8.5°C, respectively; Table 4). In 2011, daily mean water temperature in the Indian River ranged from 6.6 to 10.0°C, peaking on August 20 (2 days later than 2010).

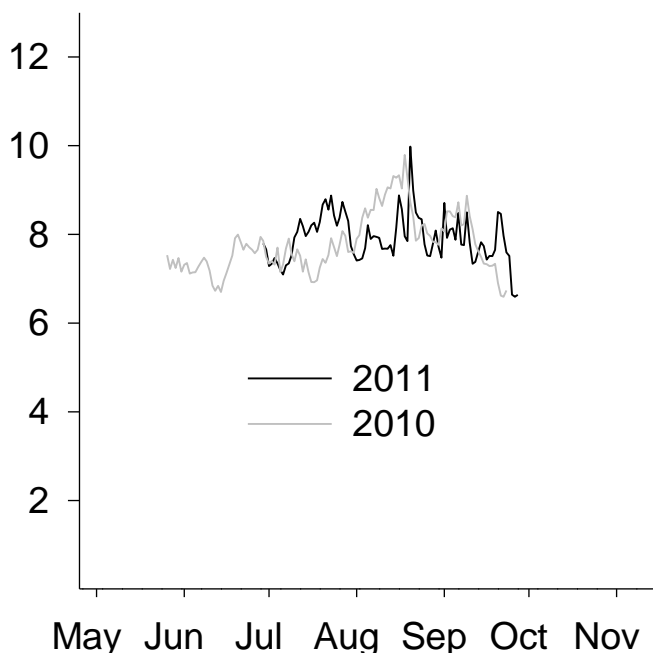


Figure 11. Daily mean water temperature for the Indian River in 2010 and 2011.

Conductivity, DO, and pH

The 2011 ranges for conductivity, DO, and pH values in the Indian River (Figure 6) were very similar to 2010, although like the Salmon River data, direct comparisons of the distributions are difficult due to differing sampling windows between years. In 2011, daily average conductivity ranged from 0.02 to 0.05 mS/cm with a median of 0.04 mS/cm. DO ranged from 10.5 to 12.4 mg/L with a median of 11.7 mg/L. Daily average values for pH ranged from 6.7 to 7.3 with a median of 7.0. The Indian River demonstrated large drops in pH that coincided with large precipitation events. The most dramatic drop occurred during a large 8.3 cm rain event recorded at the Sitka Airport on August 20; pH dropped below 6.5 for two hourly readings and quickly rose upward after the event.

Compliance with water quality standards

2011 observations (Table 5) do not indicate chronic exceedances of Alaska Department of Environmental Conservation water quality standards (Table 6; ADEC 2011) and water quality values in the three rivers generally never approached regulatory thresholds. In the Indian River, pH dropped below the minimum ADEC threshold of 6.5 for two hourly readings on August 20.

The weekly average pH of all hourly readings from August 18 to 24 was 6.9. The Taiya River experiences occasional spikes in turbidity caused by the natural condition of glacial runoff conditions (Figure 8; Appendix B, Figure 15). No anthropogenic development exists in the drainage basin upstream of the monitoring station, and the primary human impact in the area involves hiking along the adjacent Chilkoot Trail.

Table 5. Period of record and summary statistics for all freshwater water quality collected and reported by the SEAN.

River	Parameter	Period of Record	Number of observations ¹	Summary statistics				
				Median	Mean	Standard deviation	Minimum	Maximum
Salmon	Conductivity (mS/cm)	4 June 2010 to 30 September 2011	6732	0.21	0.20	0.07	0.05	0.39
	Dissolved Oxygen (mg/L)		6732	10.4	10.5	0.8	8.5	13.0
	Dissolved Oxygen (% Sat)		6732	88.9	88.8	6.4	73.3	105.9
	pH		6732	7.9	7.9	0.1	7.1	8.1
	Temperature (°C)		6732	8.4	8.1	1.6	3.8	12.4
Taiya	Conductivity (µS/cm)	25 April 2011 to 14 November 2011	3628	0.05	0.05	0.02	0.02	0.09
	Dissolved Oxygen (mg/L)		3628	12.6	12.6	0.4	11.5	14.3
	Dissolved Oxygen (% Sat)		3628	98.4	98.3	1.9	92.6	110.5
	pH		3628	7.5	7.5	0.1	7.2	8.0
	Temperature (°C)		3628	4.9	4.9	1.5	0	9.6
Indian	Turbidity (NTU)	26 May 2010 to 27 September 2011	3628	22.4	27.2	26.0	1.0	229.6
	Conductivity (µS/cm)		4391	0.05	0.04	0.01	0.01	0.06
	Dissolved Oxygen (mg/L)		4391	11.9	11.7	0.8	9.5	13.2
	Dissolved Oxygen (% Sat)		4391	100.3	98.4	5.8	82.2	108.8
	pH		4391	7.2	7.1	0.1	6.4	7.7
	Temperature (°C)		4391	7.8	7.8	0.7	5.9	10.7

¹ Data graded '2' or '3' were not counted as observations; Please see SOP 13 of the Freshwater Water Quality protocol (Nagorski et al. 2012) for descriptions of these record quality ratings

Table 6. Currently, the most stringent Alaska Department of Environmental Conservation (ADEC) water quality standards (ADEC 2011). Superscript numbers denote the category of water quality standard.

Parameter	Criteria
Conductivity	None listed by ADEC
Dissolved oxygen (DO) ¹	DO must be greater than 7 mg/l in waters used by anadromous or resident fish. In no case may DO be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel used by anadromous or resident fish for spawning (see note 2). For waters not used by anadromous or resident fish, DO must be greater than or equal to 5 mg/l. In no case may DO be greater than 17 mg/l. The concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection.
pH ¹	May not be less than 6.5 or greater than 8.5. May not vary more than 0.5 pH unit from natural conditions.
Temperature ^{1,2}	May not exceed 20°C at any time. The following maximum temperatures may not be exceeded, where applicable: Migration routes 15°C Spawning areas 13°C Rearing areas 15°C Egg & fry incubation 13°C For all other waters, the weekly average temperature may not exceed site-specific requirements needed to preserve normal species diversity or to prevent appearance of nuisance organisms.
Turbidity ³	May not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 15 NTU. May not exceed 5 NTU above natural turbidity for all lake waters.

¹ Growth and propagation of fish, shellfish, other aquatic life, and wildlife

² Water supply/aquaculture

³ Water recreation

Discussion

Salmon River

Before the 2010 field season, no known long-term water quality records existed for the Salmon River (Eckert et al. 2006a). Data from previous short-term monitoring in a similar nearby basin, Falls Creek, are similar to 2010 and 2011 Salmon River data (Sergeant 2012). There were no notable differences in the ranges of observed Salmon River water quality between 2010 and 2011. For the Salmon River, we believe that the greater late season variation observed for DO and pH are caused by a greater occurrence and magnitude of precipitation events (Sergeant et al. 2012). During drier periods, variation is dampened by consistent input from wetlands, which constitute a large percentage of the Salmon River's drainage area.

Taiya River

2011 marked the start of the first long-term effort to continuously monitor water quality in the Taiya River watershed (Hood et al. 2006). Three turbidity measurements collected in the Taiya River between 1976 and 1985 ranged from 1 to 25 FTU (formazin turbidity units; roughly equivalent to NTU). The Hood et al. (2006) KLGO watershed assessment correctly inferred that elevated turbidity levels would be correlated with heavy rainfall or increased glacial melt (Appendix B; Figure 15). During these high flow periods in 2011, turbidity measurements peaked at 229.6 NTU.

Between 1969 and 2004, 27 individual conductivity and pH values were collected in the Taiya River by USGS across varied months. Conductivity values ranged from 0.017 to 0.114 mS/cm, while pH ranged from 7.0 to 8.0. Between 1976 and 2004, 11 individual DO measurements taken across varied months ranged from 12.6 to 13.9 mg/L (data accessed 27 February 2012 from USGS Taiya River Gauge #15056210: http://waterdata.usgs.gov/nwis/nwisman/?site_no=15056210&agency_cd=USGS). Values for all three of these parameters in 2011 were within a similar range as historically observed at the same site (Table 5).

Indian River

Like the Salmon River, before the 2010 field season, no known long-term water quality records existed for the Indian River (Eckert et al. 2006b). There were no notable differences in the ranges of observed Salmon River water quality between 2010 and 2011.

Network-wide observations

Water quality observations in 2010 and 2011 were consistent with the expected results for a gradient of streams moving from a mostly surface water-influenced system (Indian River), to a mostly groundwater and mature wetland-influenced system (Salmon River). The heavily glaciated Taiya River watershed demonstrates less predictable water quality patterns in comparison, and should provide an interesting contrast to the non-glacial systems in future years. Among all three rivers, thermal regimes differ noticeably. Several years of high resolution water temperature data will provide a unique opportunity to characterize the thermal patterns across the gradient of Southeast Alaska streams, from clearwater to brownwater to glacial.

No observed values or trends appeared to signal point source pollution or a change to the fundamental water quality of the Salmon, Taiya, or Indian Rivers. Throughout the monitoring period, all three rivers exhibited water quality conditions within expected normal ranges.

Considerations

Significant gaps in 2011 data collection will likely be avoided in future sampling years. Some problems were caused by not following protocol guidelines correctly or unavoidable instrument malfunction. Pre-season training for 2012 will address the observed 2011 mistakes directly and discuss the importance of following protocol procedures carefully to avoid errors in the field. Improperly manufactured wiper shafts caused leaking oxygen sensors in 2011, but this defect has been remedied by YSI, Inc. and should not occur in the future.

A September calibration check was not possible in the Indian River due to sediment clogging the ABS pipe housing the water quality sonde. Future installations for all rivers will include a cap and bolt for the top of the pipe that will block sediment from entering the top of the tube due to vandalism or high river flows.

Currently, SEAN does not correct (adjust) data values based on calibration checks (see Wagner et al. 2006), but will develop a proposal for considering future data correction procedures around early 2013. If data customers decide that analyses may benefit from data correction, all data necessary to develop correction procedures are available on the SEAN website (e.g., site visit worksheets including calibration check results).

SEAN regards temperature monitoring as a high priority in the coming years (Nagorski et al. 2012). Due to the low cost of temperature logging sensors and ease of installation and maintenance, a network of temperature sensors across streams in all three parks is very feasible. Freshwater water temperature is an important environmental driver in Southeast Alaska that is directly influenced by glacial melt and atmospheric temperature shifts due to climate change. High resolution data is needed to properly document shifting temperatures and validate predictions of temperature changes for the coming decades.

Readers interested in accessing SEAN water quality data can download data from the SEAN Freshwater Water Quality webpage: http://science.nature.nps.gov/im/units/sean/FQ_Main.aspx

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Appendix A: Hourly time series data by river for all water quality parameters

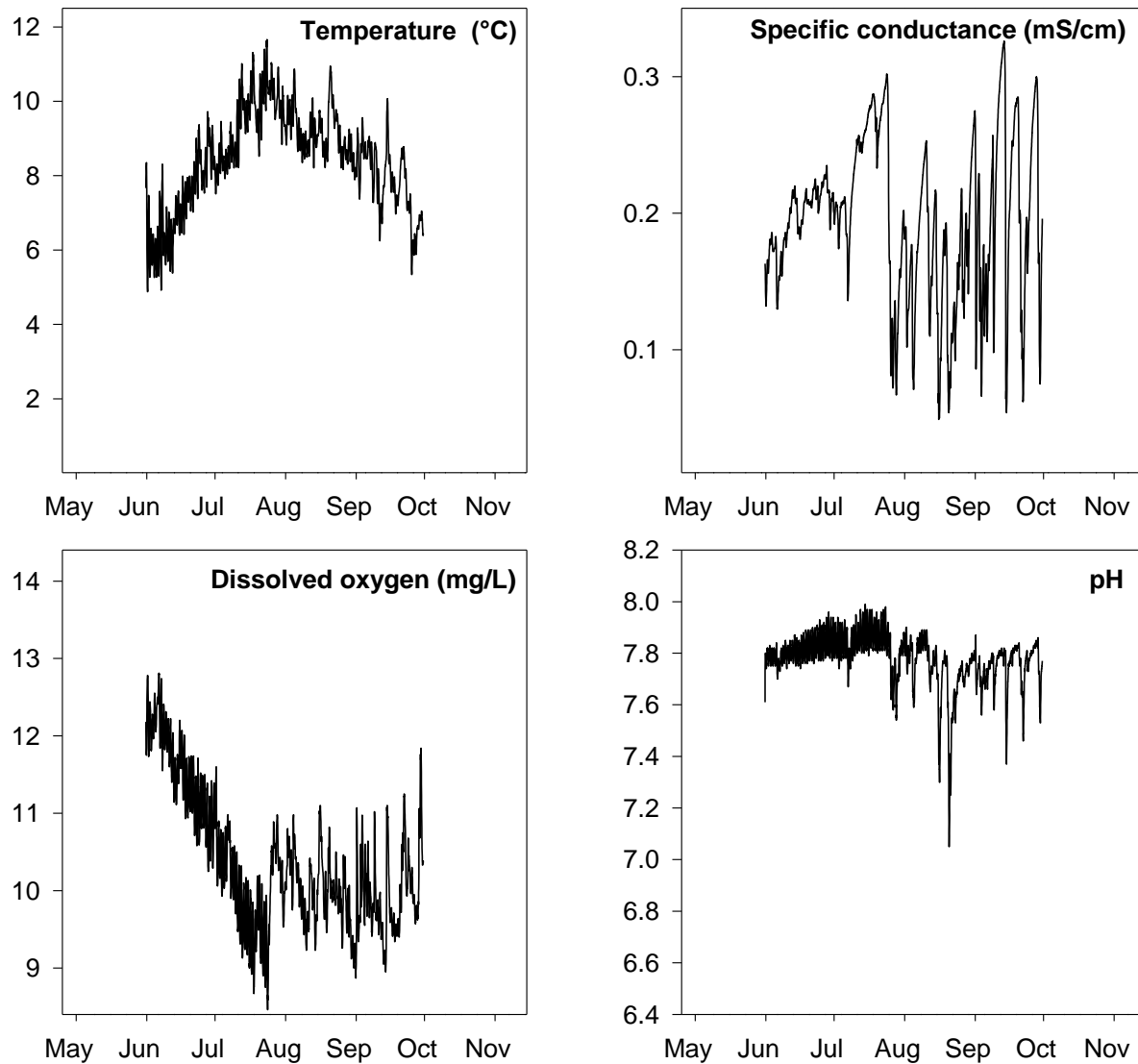


Figure 12. Hourly water quality data for the Salmon River in 2011.

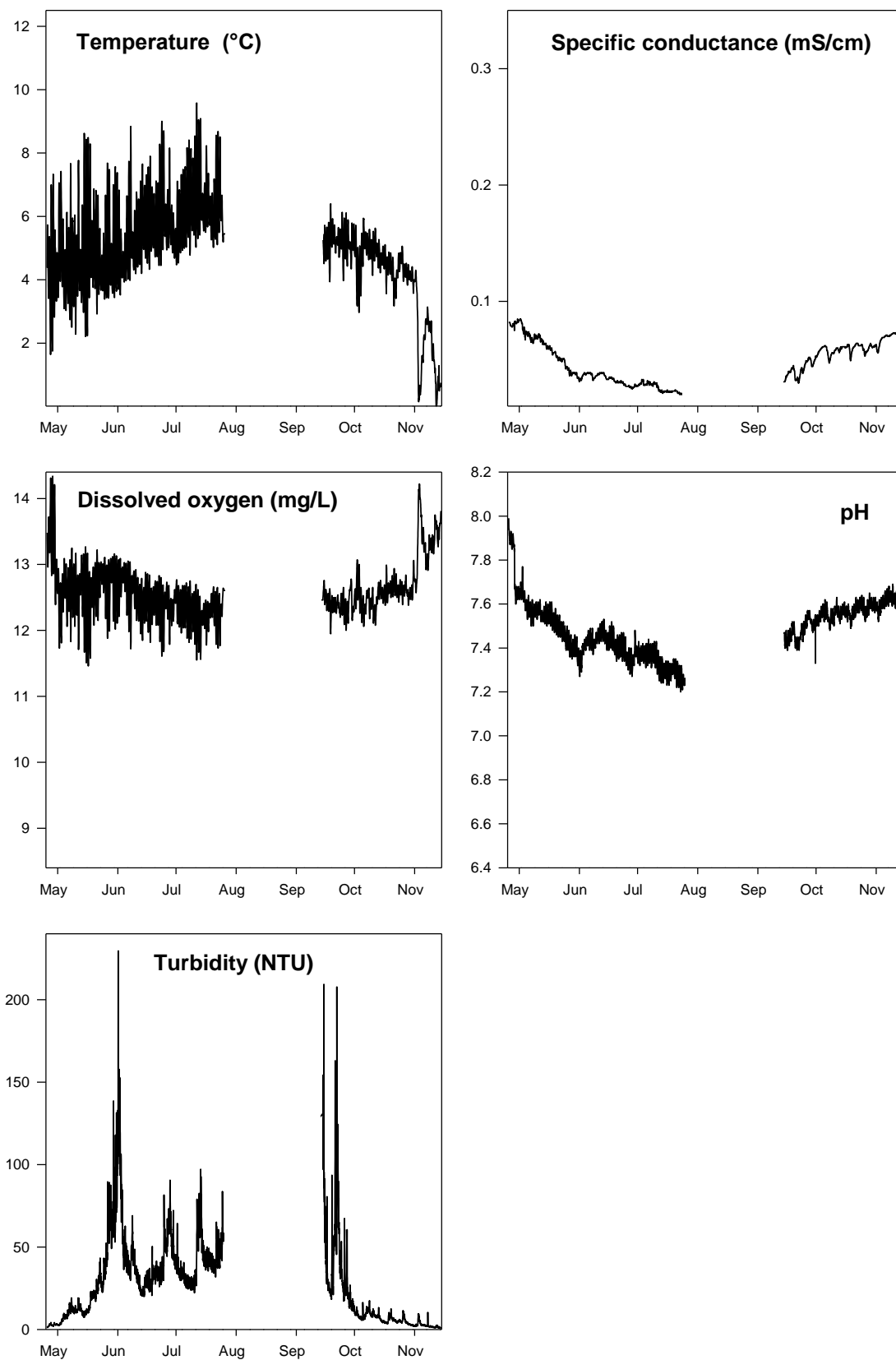


Figure 13. Hourly water quality data for the Taiya River in 2011.

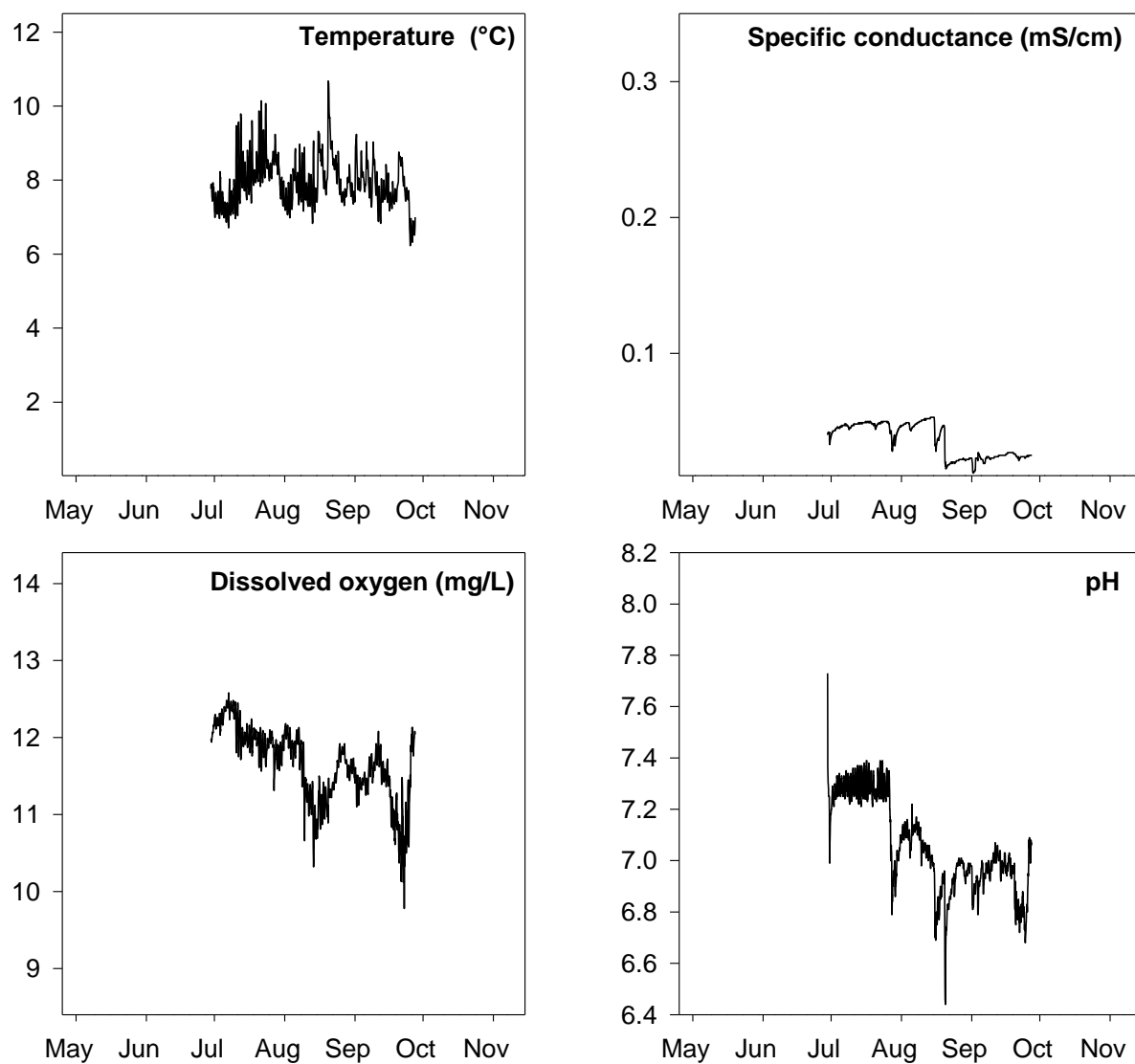


Figure 14. Hourly water quality data for the Indian River in 2011.

Appendix B: Taiya River streamflow time series versus all water quality parameters

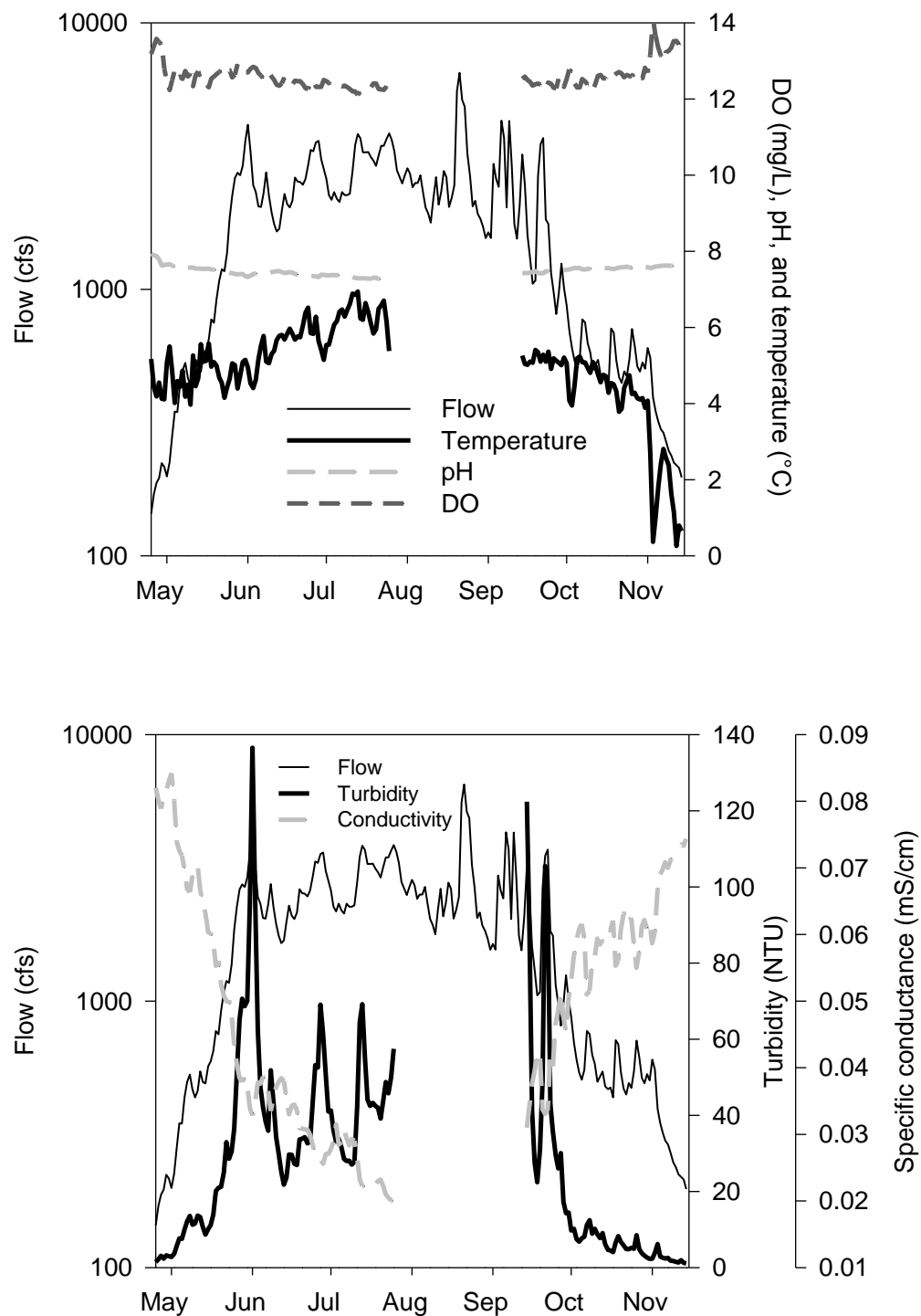


Figure 15. Daily average streamflow (log scale) versus daily averages for all water quality parameters in the Taiya River in 2011. Note the additional Y-axes on each panel. Streamflow data collected in the same location as water quality data and downloaded from the Taiya River USGS gage #1505621 website (http://waterdata.usgs.gov/ak/nwis/uv/?site_no=15056210&PARAMeter_cd=00065,00060).

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NPS 965/113241, March 2012

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